Stroke

TOPICAL REVIEW

Section Editors: Julie Bernhardt, PhD, and Pam Duncan, PhD

Perceptual Disorders After Stroke: A Scoping Review of Interventions

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ABSTRACT: Perceptual disorders relating to hearing, smell, somatosensation, taste, touch, and vision commonly impair stroke survivors' ability to interpret sensory information, impacting on their ability to interact with the world. We aimed to identify and summarize the existing evidence for perceptual disorder interventions poststroke and identify evidence gaps. We searched 13 electronic databases including MEDLINE and Embase and Grey literature and performed citation tracking. Two authors independently applied a priori–defined selection criteria; studies involving stroke survivors with perceptual impairments and interventions addressing those impairments were included. We extracted data on study design, population, perceptual disorders, interventions, and outcomes. Data were tabulated and synthesized narratively. Stroke survivors, carers, and clinicians were involved in agreeing definitions and organizing and interpreting data. From 91 869 records, 80 studies were identified (888 adults and 5 children); participant numbers were small (median, 3.5; range, 1–80), with a broad range of stroke types and time points. Primarily focused on vision (34/80, 42.5%) and somatosensation (28/80; 35.0%), included studies were often case reports (36/80; 45.0%) or randomized controlled trials (22/80; 27.5%). Rehabilitation approaches (78/93; 83.9%), primarily aimed to restore function, and were delivered by clinicians (30/78; 38.5%) or technology (28/78; 35.9%; including robotic interventions for somatosensory disorders). Pharmacological (6/93; 6.5%) and noninvasive brain stimulation (7/93; 7.5%) approaches were also evident. Intervention delivery was poorly reported, but most were delivered in hospital settings (56/93; 60.2%). Study outcomes failed to assess the transfer of training to daily life. Interventions for stroke-related perceptual disorders are underresearched, particularly for pediatric populations. Evidence gaps include interventions for disorders of hearing, taste, touch, and smell perception. Future studies must involve key stakeholders and report this fully. Optimization of intervention design, evaluation, and reporting is required, to support the development of effective, acceptable, and implementable interventions.

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Perception is our ability to understand and organize information from our sensory systems: hearing, smell, somatosensation, taste, touch, and vision. Perceptual disorders are frequently undetected[1,2] but may affect up to 74% of stroke survivors[3–5] and persist for months or years post-onset.[3,6,7] Perceptual disorders impact on stroke survivors' ability to make sense of and interact with their environment, through recognition, differentiation, organization, and integration of sensory information,[8,9] impeding recovery and rehabilitation,[10] self-care,[11] and independence in everyday activities.[3,12]

Assessment and management of perceptual problems poststroke is complex, due to the range of sensory systems and specialisms involved. Significant variability

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exists in care provision,[13] pathways,[1,13] and stroke team training on perception and terminology.[2,14] While stroke guidelines refer to perception, treatment recommendations focus on specific domains, and guidance on intervention selection or delivery is limited.[15–17] Intervention research is a priority for stroke survivors, carers, and health care professionals.[18,19]

Previous intervention evidence reviews are fragmented, addressing single sensory domains,[20] specific anatomic areas,[21] individual perceptual disorders,[22] or specific interventions,[23] while others include mixed populations inclusive of nonperceptual disorders or nonstroke etiologies.[24,25] An accessible, comprehensive, up-to-date evidence review relevant to stroke survivors, carers, and clinicians is required. We aimed to identify, map, and synthesize evidence relating to perceptual disorder interventions poststroke in a scoping review, providing a broad overview of the evidence and identifying research gaps.

METHODS

There is much variation in the meaning assigned to the term perception: it varies in relation to definition, delineation from sensation and cognition, and included disorders; it also varies across senses, clinical specialisms, and time. We defined perception as "specific mental functions of recognizing and interpreting sensory stimuli"[26] and applied it across disorders relating to hearing, smell, somatosensation (including proprioception), taste, touch, and vision (including visuospatial; see Methods S1 for definitions).

Our scoping review followed a predefined protocol (CRD42019160270), established methodology,[27,28] and relevant reporting guidelines.[29] Scoping review methodology provides a structured, rigorous approach to providing an overview of a range of evidence, research gaps, and future research priorities.[27,28] Thirteen databases (including MEDLINE, Embase, and CINAHL), specialized resources, and trial registers were searched (inception to February 7, 2020). To address the breadth of included sensory domains and complex perceptual terminology, our multidisciplinary research team worked with stakeholders (stroke survivors and carers, n=5; experienced clinicians with expertise in perceptual disorders, n=4) and an information specialist to develop a peer-reviewed search[30] (Methods S1). Extensive supplementary searching included backward and forward citation tracking (last search: November 24, 2020; Methods S1). No language or date limitations were applied. We included studies where participants had poststroke perceptual disorders and explored interventions that targeted that disorder. We included all age groups, stroke types, and settings.

Two reviewers independently screened abstracts and full texts. We anticipated challenges in the application of our perceptual disorder inclusion criteria: where uncertainties arose, a third (clinical expert) reviewer was consulted. Data were charted and categorized by 1 reviewer using predefined, piloted forms and checked by a second, with input from clinical experts as required. Extracted data included study design, participant demographics, intervention details (using the Template for Intervention Description and Replication [TIDieR] checklist),[31] and outcome measurements. Where studies recruited mixed participant populations, stroke- and perception-specific data were extracted, where possible. Extensive data categorization profiled the complex disorders and interventions' distinguishing features (Table S1). Intervention categorization used an established taxonomy,[32,33] including pharmacological, noninvasive brain stimulation (NIBS; such as transcranial direct current stimulation), or rehabilitation. Rehabilitation interventions were subcategorized as restitution (direct training of the impaired function), compensation (via training of or using a spared function), substitution (use of an external device or modification),[34] or a combination of these approaches. All categorizations were checked by a third reviewer and considered the body functions (impairments) the intervention targeted, as stated by the primary research teams; we made no assumptions about biological mechanisms at play.

We categorized outcomes used by the primary researchers to measure intervention effectiveness. We extracted verbatim summaries of individual study findings. As the aim was to provide an overview of the scope of research, rather than judge the quality of evidence for a specific intervention, no assessment of methodological quality or detailed aggregation of findings was conducted.[27]

Data were collated and tabulated. A narrative account was organized by sense and intervention approach. Our stakeholder group contributed to this process and data interpretation[35,36] (Methods S2). The appropriate guidance was used to report the review (Methods S3). The review data are available from the corresponding author upon reasonable request.

RESULTS

Results of the Search

Of 91 869 titles identified, 80 (893 participants; 869 poststroke perceptual disorders) met our inclusion criteria (Figure 1; Table S2). Interventions and participants were summarized by perceptual disorder: vision (Table 1), somatosensation (Table 2), and other sensory domains (Table 3).

Included Studies

Case reports (36/80; 45.0%) and randomized controlled trials (RCTs; 22/80; 27.5%) were common, with RCTs accounting for most participants (630/893; 70.5%). Study sample sizes ranged from 1 to 80 participants (median, 3.5; interquartile range, 1–16.5). Most were based in Asia (27/80; 33.8%) or Europe (26/80; 32.5%). Study numbers are increasing with time (Figure 2A); of RCTs, 54.5% (12/22) were conducted 2015 to 2020. Involvement of stakeholders, such as stroke survivors, carers, or clinicians, in the research development and delivery (as opposed to as participants) was not reported in any included studies.

Time point poststroke ranged between <1 month (19/80; 23.8%), 1 to 6 months (25/80; 31.3%), and >6 months (20/80; 25.0%). Right hemisphere lesions were common (39/80 studies [48.8%] recruited >60%

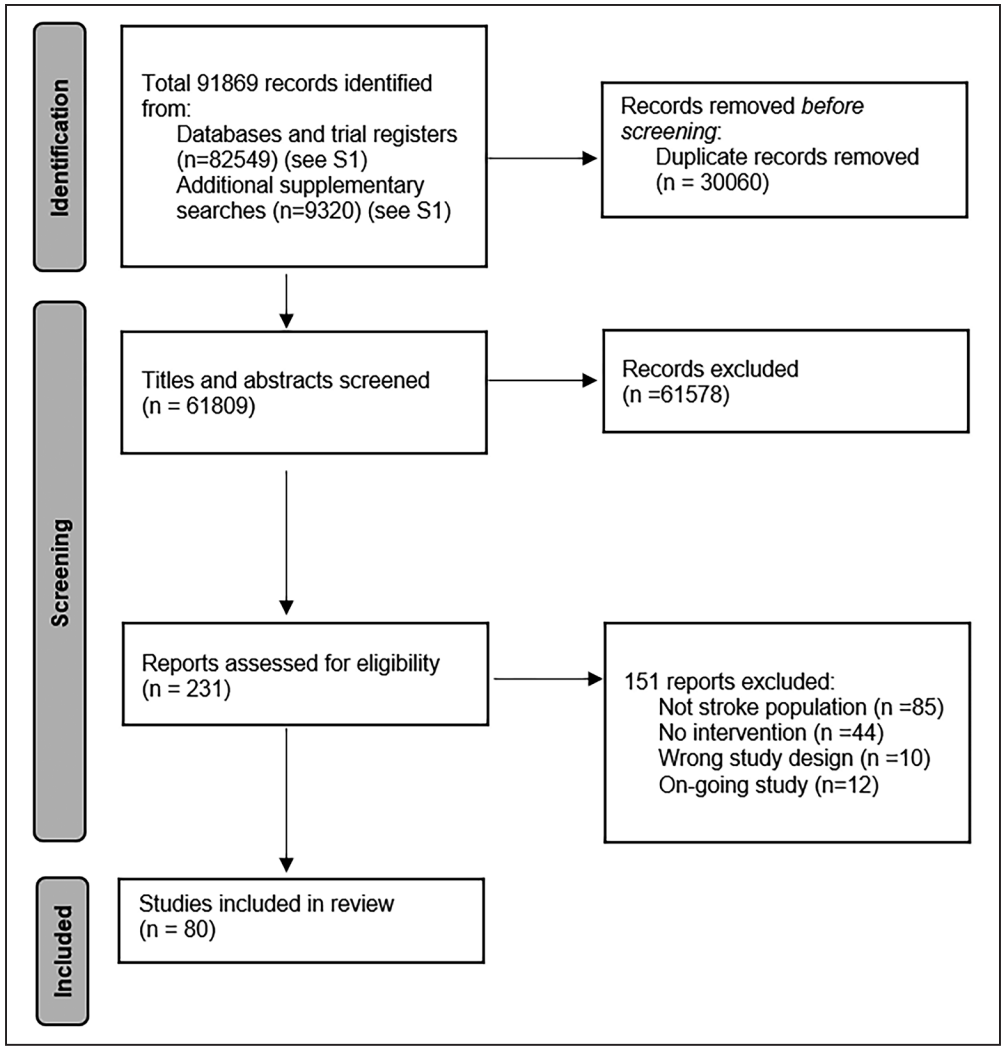

Figure 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) diagram for scoping review literature identification.

participants with right-sided lesions), and the mean proportion of women was 34.8% (SD, 33.8). Stroke severity was rarely reported (13/80; 16.3%). Young people (<18 year olds) were represented by 5 single case reports, all describing visual perceptual disorders; the remaining study participants were most commonly aged 18 to 65 years (43/80; 53.8%; Table S3).

Nature of Perceptual Disorder

Vision (34/80; 42.5% studies; n=357/893; 40.0%) and somatosensation disorders (28/80; 35.0% studies; n=303/893; 33.9%) were most frequently reported. Common disorders included Pusher syndrome[37] (24 studies), visual perceptual deficits (16 studies), and visual hallucination (8 studies; Figure 2B; disorder definitions in Table S4).

There was variation in study designs addressing each sense (Figure 2C). Some clusters emerged, with specific designs and interventions for specific perceptual disorders; 5 pharmacological intervention case studies examined visual/audiovisual hallucinations; 6 RCTs addressed Pusher syndrome rehabilitation interventions.

Interventions

Ninety-three perceptual disorder interventions were described across 80 studies (Table S5). Rehabilitation interventions were common (78/93; 83.9%) and primarily restitutive in nature (45/93; 48.4%). Other interventions included NIBS (7/93; 7.5%) and pharmacological interventions (6/93; 6.5%; Figure 2D). Surgical and assessment-based interventions were absent.

Overview of the Interventions and Intervention Provider

Interventions often involved therapeutic input from a health care practitioner (HCP; 30/93; 32.3%), such as training and support during specific physical activities, rather than physical materials. Technology-based

Table 1. Visual Perceptual Disorders: Details of Studies, Population, and Interventions

Study: author (year); design; country	Population; (1) and (2) refer to participant groups within studies	Stroke	Intervention: approach; description	Delivery: materials; who; how; where	Session details	Duration
Chen (2011); CR; Taiwan	n=1; age, 70 y	Perceptual disorder: Charles Bonnet syndrome; time post-stroke: NR; %R hemisphere: 81%–100%R	Pharmacological; quetiapine, then ariprazole	Pharmacological; unclear; 1-1; in/outpatient	Dosage: 5 mg; frequency: daily; n of sessions: 21	3/52 wk; 21/365 d
Nakagawa (1999); CR; China	n=1; age, 70 Y	Perceptual disorder: Charles Bonnet syndrome; time poststroke: <1 mo; %R hemisphere: 0%–20%R	Pharmacological; dobutamine	Pharmacological; unclear; 1-1; inpatient	Dosage: 5μg/kg per min; frequency: NR; n of sessions: NR	NR; NR
Nguyen (2011); CR; the United States	n=1; age, 75 y	Perceptual disorder: Charles Bonnet syndrome; time poststroke: <1 mo; %R hemisphere: NR	Pharmacological; haloperidol	Pharmacological; medic; 1-1; NR	Dosage: NR; frequency: nightly; n of sessions: NR	NR; NR
Roberts-Woodbury (2016); CR; NR	n=1; age, 69 y	Perceptual disorder: Charles Bonnet syndrome; time poststroke: 1–6 mo; %R hemisphere: NR	Pharmacological; risperidone	Pharmacological; unclear; NR; inpatient	Dosage: NR; frequency: NR; n of sessions: NR	NR; NR
Cogan (1973); CR; the United States	n=1; age, 72 y	Perceptual disorder: other visual hallucination; time poststroke: NR; %R hemisphere: 81%–100%R	Pharmacological; librium	Pharmacological; unclear; NR; NR	Dosage: NR; frequency: NR; n of sessions: NR	NR; NR
Flint (2005); CR; the United States	n=1; age, 64 y	Perceptual disorder: other visual hallucination; time poststroke: NR; %R hemisphere: 0%–20%R	Rehab (substitution); cardboard mask covering left side of glasses	Spec equipment; other; self-delivery; NR	Length: NR; frequency: NR; n of sessions: NR	Unclear; NR
Poetter (2012); CR; the United States	n=1; age, 63 y	Perceptual disorder: other visual hallucination; 1–6 mo; %R hemisphere: 81%–100%R	Rehab (unclear); cognitive rehabilitation for neglect	NR; NR; NR; inpatient	Length: NR; frequency: NR; n of sessions: NR	NR; NR
Rafique (2016); CR; Canada	n=1; age, 30 y	Perceptual disorder: other visual hallucination; time poststroke: >6 mo; %R hemisphere: 81%–100%R	NIBS; rTMS using 70 mm diameter figure-of-eight coil and 1 Hz pulse at 85% of maximum output	NIBS; NR; 1-1; NR	Length: 30 min; frequency: daily; n of sessions: 5	1/52 wk; 2.5/24 h
Brunsdon (2017); CR; Australia	n=1; age, 6 y	Perceptual disorder: visual agnosia; time poststroke: >6 mo; %R hemisphere: 81%–100%R	Rehab (compensation); verbally mediated topographical orientation and route training	HCP led; teacher; 1-1; school	Length: unclear; frequency: unclear; n of sessions: unclear	12/52 wk; unclear
Tanemura (1999); CR; Japan	n=1; age, 56 y	Perceptual disorder: visual agnosia; time poststroke: 1–6 mo; %R hemisphere: 0%–20%R	Rehab (restitution and compensation); practical activities including sketching, word carving, mosaic work, and fishing	HCP led; NR; 1-1; inpatient	Length: NR; frequency: NR; n of sessions: NR	NR; NR
Zihl (2000 [4]); CR; Germany	n=1; NR	Perceptual disorder: visual agnosia; time poststroke: NR; %R hemisphere: 0%–20%R	Rehab (restitution and compensation); stepwise training, including training of letter and feature recognition	Tech based; NR; 1-1; inpatient	Length: 45 min; frequency: 2-4 per day; n of sessions: unclear	NR; NR
McDowell (2019); CR; New Zealand	n=1; age, 16 y	Perceptual disorder: visual perceptual deficit; time poststroke: >6 mo; %R hemisphere: 0%–20%R	Rehab (compensation); detailed tutorial; strategy training including emotional strategies	Other (info); other; self-delivery; home	Length: NR; frequency: NR; n of sessions: NR	NR; NR
Gottlieb (1991); CR; the United States	n=1; age, 80 y	Perceptual disorder: visual perceptual deficit; time poststroke: <1 mo; %R hemisphere: 0%–20%R	Rehab (compensation); intentional blink, gave temporary clarity	Other; other; self-delivery; in/outpatient	Length: NR; frequency: NR; n of sessions: NR	NR; NR
Burr (1970); CR; Australia	n=1; age, 74 y	Perceptual disorder: visual perceptual deficit; time post-stroke: 1–6 mo; %R hemisphere: 81%–100%R	Rehab (restitution and compensation); training in ADLs via CCTV training footage	HCP led; OT; 1-1; in/outpatient	Length: NR; frequency: NR; n of sessions: unclear	3/52 wk; NR
Cho (2015); RCT; South Korea	n=27; mean: (1) 62.9 (SD=7.2); (2) 63.6 (SD=9.3)	Perceptual disorder: visual perceptual deficit; time poststroke: >6 mo; %R hemisphere: 61%–80%R	Rehab (restitution); neurofeedback training, using computer-based games	Tech based; NR; 1-1; inpatient	Length: 30 min; frequency: 5× wk; n of sessions: 30	6/52 wk; 15/24 h
Choi (2018); RCT; South Korea	n=28; median: (1) 49.5 (IQR, 2.3); (2) 51.0 (IQR, 13.8)	Perceptual disorder: visual perceptual deficit; time poststroke: >6 mo; %R hemisphere: 61%–80%R	Rehab (restitution); WiiFit training using Balance Board	Tech based; PT; 1-1; NR	Length: 30 min; frequency: 5× wk; n of sessions: 30	6/52 wk; 15/24 h

(*Continued*)

Table 1. Continued

Study: author (year); design; country	Population; (1) and (2) refer to participant groups within studies	Stroke	Intervention: approach; description	Delivery: materials; who; how; where	Session details	Duration
Dutton (2017); CR; NR	n=1; age, 9 y	Perceptual disorder: visual perceptual deficit; time poststroke: NR; %R hemisphere: 0%–20%R	Rehab (restitution and compensation); training to detect, orient to, and grasp visual stimuli to enlarge attentional visual field	NR; NR; NR; NR	Length: half-day; frequency: 5× wk; n of sessions: 5	NR; NR
Edmans (1991); N of 1; England	n=4; range, 54–65	Perceptual disorder: visual perceptual deficit; time poststroke: 1–6 mo; %R hemisphere: 0%–20%R	Rehab (restitution); training in ADL-type tasks	HCP led; OT; 1-1; in/outpatient	Length: 45 min; frequency: 3× wk; n of sessions: 12–21	4–7/52 wk; 9–16/24 h
Edmans (2000); RCT; England	n=80; mean: (1) 69.8 (SD=9.1); (2) 67.9 (SD=11.4)	Perceptual disorder: visual perceptual deficit; time poststroke: >6 mo; %R hemisphere: 41%–60%R	Rehab (restitution); transfer of training rehabilitation	HCP led; OT; 1-1; inpatient	Length: 2.5 h; frequency: unclear; n of sessions: unclear	6/52 wk; 15/24 h
			Rehab (compensation); functional approach rehabilitation	HCP led; OT; 1-1; inpatient	Length: 2.5 h; frequency: unclear; n of sessions: unclear	6/52 wk; 15/24 h
Jo (2012); cohort; South Korea	n=17; NR	Perceptual disorder: visual perceptual deficit; time poststroke: >6 mo; %R hemisphere: 61%–80%R	Rehab (restitution); computerized cognitive rehabilitation program	Tech based; OT; 1-1; inpatient	Length: 30 min; frequency: 3× wk; n of sessions: 12	4/52 wk; 6/24 h
Kang (2009); RCT; South Korea	n=16; mean: (1) 59.5 (SD=10.7); (2) 62.5 (SD=9.6)	Perceptual disorder: visual perceptual deficit; time poststroke: 1–6 mo; %R hemisphere: 81%–100%R	Rehab (restitution); computerized visual perception rehabilitation	Tech based; OT; 1-1; inpatient	Length: 30 min; frequency: 3× wk; n of sessions: 12	4/52 wk; 6/24 h
			Rehab (restitution); computer-based cognitive rehabilitation program	Tech based; OT; 1-1; inpatient	Length: 30 min; frequency: 3× wk; n of sessions: 12	4/52 wk; 6/24 h
Kim (2011); RCT; South Korea	n=30; mean: (1) 70.7 (SD=6.6); (2) 71.4 (SD=5.2)	Perceptual disorder: visual perceptual deficit; time poststroke: 1–6 mo; %R hemisphere: NR	Rehab (restitution and compensation); Dynavision wall-mounted board user strikes when illuminated	Tech based; NR; 1-1; in/outpatient	Length: 30 min; frequency: 3× wk; n of sessions: 12	4/52 wk; 6/24 h
Zihl (2000 [3]); CR; Germany	n=3; range, 58–61	Perceptual disorder: visual perceptual deficit; time poststroke: 1–6 mo; %R hemisphere: 0%–20%R	Rehab (restitution); eye movement training on slides/computer screen	Tech based; NR; NR; NR	Length: 45 min; frequency: 3–4 per d; n of sessions: unclear	Unclear; unclear
Lincoln (1985); RCT; England	n=33; mean: 50.1 (SD=15.1)	Perceptual disorder: visual perceptual deficit; time poststroke: 1–6 mo; %R hemisphere: 41%–60%R	Rehab (restitution); perceptual training tasks	HCP led; OT; 1-1; inpatient	Length: 60 min; frequency: 4× wk; n of sessions: 16	4/52 wk; 16/24 h
Zihl (2000 [1]); CR; Germany	n=1; age, 53 y	Perceptual disorder: visual perceptual deficit; time poststroke: >6 mo; %R hemisphere: 0%–20%R	Rehab (restitution); computer-based hue discrimination training	Tech based; NR; NR; NR	Length: NR; frequency: NR; n of sessions: NR	NR; NR
Park (2015); RCT; South Korea	n=30; mean: (1) 64.7 (SD=8.9); (2) 65.2 (SD=8.0)	Perceptual disorder: visual perceptual deficit; time poststroke: 1–6 mo; %R hemisphere: NR	Rehab (restitution); computer training including visual perception, attention, memory and orientation	Tech based; NR; 1-1; in/outpatient	Length: 30 min; frequency: 5× wk; n of sessions: 20	4/52 wk; 10/24 h
O'Hare (1998); CR; Scotland	n=1; age, 8 y	Perceptual disorder: visual perceptual deficit; time poststroke: >6 mo; %R hemisphere: 0%–20%R	Rehab (mixed); educational orthography with specialist reading software	Tech based; NR; 1-1; other (home/school)	Length: NR; frequency: NR; n of sessions: NR	NR; NR
Chen (2012); RCT; the United States	n=11; mean: (1) 73.8 (8.8); (2) 74.0 (8.4)	Perceptual disorder: visual spatial deficit; time poststroke: 1–6 mo; %R hemisphere: 81%–100%R	Rehab (restitution); global processing training using Rey-Osterrieth figure	HCP led; NR; 1-1; inpatient	Length: 90 min; frequency: once; n of sessions: 1	1/365 d; 1.5/24 h
			Rehab (restitution); rote repetition training using Rey-Osterrieth figure	HCP led; NR; 1-1; inpatient	Length: 90 min; frequency: once; n of sessions: 1	1/365 d; 1.5/24 h

(*Continued*)

Table 1. Continued

Study: author (year); design; country	Population; (1) and (2) refer to participant groups within studies	Stroke	Intervention: approach; description	Delivery: materials; who; how; where	Session details	Duration
Funk (2013); cohort; Germany	n=13; range, 23–60	Perceptual disorder: visual spatial deficit; time poststroke: 1>6 mo; %R hemisphere: 81%–100%R	Rehab (restitution); line presentation on computer screen with visual feedback	Tech based; NR; 1-1; NR	Length: NR; frequency: 3× wk; n of sessions: 11	4/52 wk; NR
Zihl (2000 [2]); CR; Germany	n=1; age, 48 y	Perceptual disorder: visual spatial deficit; time poststroke: >6 mo; %R hemisphere: 0%–20%R	Rehab (restitution); 5-stage process progressing from tabletop to PC activities	Tech based; NR; NR; NR	Length: NR; frequency: NR; n of sessions: NR	NR; NR
Towle (1990); N of 1; England	n=10; NR	Perceptual disorder: visual spatial deficit; time poststroke: NR; %R hemisphere: 81%–100%R	Rehab (unclear); practicing perceptual tasks	NR; other (therapist); group; inpatient	Length: 60 min; frequency: 3× wk; n of sessions: 24	8/52 wk; 24/24 h
Gillen (2003); CR; Scotland	n=1; age, 10 y	Perceptual disorder: visual other; time poststroke: >6 mo; %R hemisphere: 0%–20%R	Rehab (mixed); adaptive compensatory approach to use strengths and abilities to compensate perceptual problem	HCP led; NR; 1-1; home	Length: NR; frequency: NR; n of sessions: NR	NR; NR
Weinburg (1982); RCT; the United States	n=35; mean: (1) 64.2 (SD=9.0); (2) 66.8 (SD=9.8)	Perceptual disorder: visual other; time poststroke: 1–6 mo; %R hemisphere: 81%–100%R	Rehab (restitution and compensation); training to anchor attention and eye movements	HCP led; NR; 1-1; in/outpatient	Length: 60 min; frequency: 5× wk; n of sessions: 20	4/52 wk; 20/24 h
Zaharia-Pushkash (2010); CR; Moldova	n=1; age, 67 y	Perceptual disorder: visual other; time poststroke: NR; %R hemisphere: 81%–100%R	Rehab (unclear); unspecified rehabilitation	NR; NR; NR; NR	Length: NR; frequency: NR; n of sessions: NR	NR; NR

Tech based: machinery, computer, and robotics. Unclear: information reported but not clear. ADL indicates activities of daily living; CR, case report; HCP, health care professional; Hz, hertz; IQR, interquartile range; NIBS, noninvasive brain stimulation; NR, not reported; OT, occupational therapist; PT, physiotherapist; RCT, randomized controlled trial; rTMS, repetitive transcranial magnetic stimulation; and Spec, specialist.

(robotics or computer) tasks were common (28/93; 30.1%), followed by other specialist tools (13/93; 14.0%; eg, training blocks of different colors and sizes).

Descriptions of intervention delivery procedures (55/93; 59.1%) and providers (54/93; 58.1%) were limited or unclear. Where reported, interventions were predominantly delivered in hospital (56/93; 60.2%) on a one-to-one basis (76/93; 81.7%) lasting ≤1 month (42/93; 45.2%). Three (3.2%) were delivered within a participant's home. Few interventions lasted >3 months (4.3%; 4/93).

Interventions for Individual Sensory Domains

Visual perception disorder interventions used the widest range of approaches: rehabilitation (restitution, 15/37; mixed, 8/37) and pharmacological (5/37; Table 1). Restitution interventions used technology (10/15), often interactive computer-based training of visual skills, while HCP-led interventions taught compensatory skills in real-world simulation tasks. Pharmacological interventions exclusively addressed hallucinations but were solely reported in case reports, with limited details. Vision studies were lacking information on who delivered interventions, where, and for how long.

Four somatosensory disorder intervention approaches were used: rehabilitation (restitution, 24/35; mixed, 6/35), NIBS (3/35), and rehabilitation+NIBS (2/35; Table 2). Most often, interventions were HCP led (17/35), involving physical activities to retrain postural control, with technology-based interventions (9/35) often providing robot-assisted gait training. Interventions were predominantly delivered on a one-to-one basis (32/35), in an inpatient setting (18/35), for ≤1 month (25/35).

Hearing perception disorder intervention reports all describe rehabilitation approaches, primarily technology based (hearing aids; 5/7). Tactile perception disorder interventions (n=7) involved rehabilitation (n=5) or NIBS (n=2). HCPs were less involved in interventions for this disorder, using technology (n=1/5; vibrotactile stimulation) or equipment (n=4/5; tasks with different textures or hardness).

We identified no interventions targeting individual smell or taste perceptual disorders.

Outcomes Measured

The most frequently measured outcomes were perceptual function (60/80; 75.0%), motor/sensorimotor (32/80; 40%), activities of daily living (18/80; 22.5%), and sensory outcomes (12/80; 15%; Table 4). Outcomes were captured immediately (31/80; 38.8%), ≤1 month (9/80; 11.3%), 1 to 3 months (9/80; 11.3%), and >3 months (12/80; 15.0%) after intervention.

Verbatim summaries of study findings are given in Table S6.

Table 2. Somatosensation Perceptual Disorders: Details of Studies, Population, and Interventions

Study: author; design; country	Population; (1) and (2) refer to participant groups within studies	Stroke	Intervention: approach; description	Delivery: materials; who; how; where	Session details	Duration
Ko (2018); CC; South Korea	n=14; mean: 65.2 (SD=7.8)	Perceptual disorder: proprioceptive deficit; time poststroke: <1 mo; %R hemisphere: 41%–60%R	Rehab (restitution); Frankel exercises	HCP led; PT; 1-1; in/outpatient	Length: 15 min; frequency: 5× wk; n of sessions: 15	3/52 wk; 3.45/24 h
An (2019); RCT; South Korea	n=14; mean: (1) 59.3 (SD=4.6); (2) 64.4 (SD=7.5)	Perceptual disorder: Pusher syndrome; time poststroke: <1 mo; %R hemisphere: 81%–100%R	Rehab (restitution); game-based postural vertical training using whole-body tilt equipment	Tech based; NR; 1-1; inpatient	Length: 30 min twice daily; frequency: 5× wk; n of sessions: 30	3/52 wk; 15/24 h
			Rehab (restitution); conventional postural vertical training using posture control training exercises	HCP led; NR; 1-1; inpatient	Length: 30 min twice daily; frequency: 5× wk; n of sessions: 30	3/52 wk; 15/24 h
An (2020); RCT; South Korea	n=30; mean: (1) 60.5 (SD=6.0); (2) 64.7 (SD=6.9)	Perceptual disorder: Pusher syndrome; time poststroke: <1 mo; %R hemisphere: 61%–80%R	Rehab (restitution); whole-body tilting postural training using A Spine Balance 3D	Tech based; PT; 1-1; inpatient	Length: 30 min twice daily; frequency: 5× wk; n of sessions: 30	3/52 wk; 15/24 h
			Rehab (restitution); general postural training using visual feedback and weight shifting	HCP led; PT; 1-1; inpatient	Length: 30 min twice daily; frequency: 5 wk; n of sessions: 30	3/52 wk; 15/24 h
Bergmann (2018); RCT; Germany	n=38; mean: (1) 72 (SD=9); (2) 71 (SD=10)	Perceptual disorder: Pusher syndrome; time poststroke: 1–6 mo; %R hemisphere: 61%–80%R	Rehab (restitution and substitution); robot-assisted gait training with Lokomat	Tech based; NR; 1-1; inpatient	Length: 60 min; frequency: 5× wk; n of sessions: 8–10	2/52 wk; 8–10/24 h
			Rehab (restitution); postural control training including sensory feedback	HCP led; PT; 1-1; inpatient	Length: 60 min; frequency: 5× wk; n of sessions: 8–10	2/52 wk; 8–10/24 h
Broetz (2004); cohort; Germany	n=8; median: 63 (range, 51–79)	Perceptual disorder: Pusher syndrome; time poststroke: <1 mo; %R hemisphere: 81%–100%R	Rehab (restitution); physiotherapy with visual feedback to demonstrate body orientation	HCP led; NR; 1-1; inpatient	Length: 30 min; frequency: 6× wk; n of sessions: unclear	Unclear; unclear
Freitas (2017); CR; Brazil	n=1; age, 62.5 y	Perceptual disorder: Pusher syndrome; time poststroke: >6 mo; %R hemisphere: 81%–100%R	Rehab (restitution); mirror therapy using balance and reach training	HCP led; NR; 1-1; outpatient	Length: 50 min; frequency: 3× wk; n of sessions: 13	5/52 wk; 12.5/24 h
Fujino (2016); N of 1; Japan	n=3; age, unclear	Perceptual disorder: Pusher syndrome; time poststroke: <1 mo; %R hemisphere: NR	Rehab (restitution); relaxation therapy in prone position using treatment table	HCP led; NR; 1-1; in/outpatient	Length: 10 min; frequency: daily; n of sessions: 6	6/365 d; 1/24 h
Fujino (2019); N of 1; Japan	n=2; age, 69–75 y	Perceptual disorder: Pusher syndrome; time poststroke: <1 mo; %R hemisphere: 81%–100%R	Rehab (restitution and substitution); electromyography-guided electrical stimulation therapy	Tech based; NR; 1-1; NR	Length: 65 min; frequency: twice; n of sessions: unclear	2/365 d; 2/24 h
Gillespie (2019); CR; the United States	n=1; age, 58 y	Perceptual disorder: Pusher syndrome; time poststroke: <1 mo; %R hemisphere: 81%–100%R	Rehab (restitution and substitution); standing frame	HCP led; PT; group; inpatient	Length: unclear; frequency: unclear; n of sessions: unclear	18/52 wk; 6.5/24 h (380 total min)
Jahn (2017); CR; Germany	n=1; age, 81 y	Perceptual disorder: Pusher syndrome; time poststroke: 1–6 mo; %R hemisphere: 81%–100%R	Rehab (restitution and substitution); Spacecurl: suspension device with 3D rotation	Spec equipment; PT; 1-1; inpatient	Length: 30 min; frequency: 3× wk; n of sessions: 12	4/52 wk; 6/24 h
Jang (2018); CR; South Korea	n=1; age, 67 y	Perceptual disorder: Pusher syndrome; time poststroke: <1 mo; %R hemisphere: 81%–100%R	Rehab (restitution); rehabilitative therapy with movement therapy and somatosensory stimulation	NR; NR; 1-1; inpatient	Length: unclear; frequency: 5× wk; n of sessions: 80	16/52 wk; unclear
Jokelainen (2000); CR; Finland	n=1; age, 78 y	Perceptual disorder: Pusher syndrome; time poststroke: <1 mo; %R hemisphere: 81%–100%R	Rehab (restitution); occupational therapy and physiotherapy rehabilitation programme	HCP led; PT; 1-1; inpatient	Length: unclear; frequency: 5× wk; n of sessions: unclear	Unclear; unclear

(*Continued*)

Table 2. Continued

Study: author; design; country	Population; (1) and (2) refer to participant groups within studies	Stroke	Intervention: approach; description	Delivery: materials; who; how; where	Session details	Duration
Kim (2016); other; South Korea	n=10; mean: (1) 63.1 (SD=12.3); (2) 62.4 (SD=14.9)	Perceptual disorder: Pusher syndrome; time poststroke: 1–6 mo; %R hemisphere: 41%–60%R	Rehab (restitution and substitution); virtual reality visual feedback during Lokomat training	Tech based; NR; 1-1; in/outpatient	Length: 30 min twice daily; frequency: 5× wk; n of sessions: 40	4/52 wk; 20/24 h
Lee (2017); N of 1; South Korea	n=3; range, 58–65	Perceptual disorder: Pusher syndrome; time poststroke: 1–6 mo; %R hemisphere: NR	Rehab (restitution); postural vertical training with/without visual feedback	HCP led; NR; 1-1; inpatient	Length: 60 min; frequency: 3× wk; n of sessions: 18	6/52 wk; 18/24 h
Menghetti (2009); CR; Brazil	n=1; age, 78 y	Perceptual disorder: Pusher syndrome; time poststroke: NR; %R hemisphere: NR	Rehab (restitution); aquatic physiotherapy using Bad Ragaz and Halliwick methods	HCP led; PT; 1-1; other (teaching clinic)	Length: 60 min; frequency: 2× wk; n of sessions: 16	8/52 wk; 16/24 h
Mikolajewska (2012); CR; Poland	n=1; age, 72 y	Perceptual disorder: Pusher syndrome; time poststroke: 1–6 mo; %R hemisphere: 81%–100%R	Rehab (restitution); contraversive Pusher syndrome therapy including visual cues	HCP led; PT; 1-1; NR	Length: unclear; frequency: unclear; n of sessions: 10	2/52 wk; unclear
Pardo (2019); CS; the United States	n=5; range, 42–76	Perceptual disorder: Pusher syndrome; time poststroke: <1 mo; %R hemisphere: 61%–80%R	Rehab (restitution); physiotherapy rehabilitation programme	HCP led; PT; 1-1; inpatient	Length: 90 min; frequency: 5× wk; n of sessions: 19 average	4/52 wk; 28.5/24 h
Scheets (2007); CR; the United States	n=1; age, 76 y	Perceptual disorder: Pusher syndrome; time poststroke: NR; %R hemisphere: 81%–100%R	Rehab (restitution); physiotherapy rehabilitation programme	HCP led; PT; 1-1; inpatient	Length: 25–45 min; frequency: daily; n of sessions: 14	2/52 wk; 7/24 h
Voos (2011); CR; Brazil	n=1; age, 65 y	Perceptual disorder: Pusher syndrome; time poststroke: >6 mo; %R hemisphere: 81%–100%R	Rehab (restitution); physiotherapy including sensory stimulation, motor training, and sensorimotor integration	HCP led; NR; unclear; home	Length: 60 min; frequency: 2× wk; n of sessions: 48	24/52 wk; 48/24 h
Wang (2016); RCT; China	n=25; NR	Perceptual disorder: Pusher syndrome; time poststroke: NR; %R hemisphere: NR	Rehab (restitution); visual feedback via a dynamic and static balance/motion control system and balance board	Spec equipment; PT; group; in/outpatient	Length: 30 min; frequency: 5× wk; n of sessions: 15	3/52 wk; 7.5/24 h
			Rehab (restitution); core stability training using exercises	Spec equipment; PT; 1-1; in/outpatient	Length: 2 h; frequency: 5× wk; n of sessions: 5	1/52 wk; 10/24 h
			Rehab (restitution); visual feedback and core stability exercises combined	HCP led; PT; 1-1; in/outpatient	Length: unclear; frequency: unclear; n of sessions: unclear	Unclear; unclear
Yang (2015); RCT; Taiwan	n=12; mean: (1) 62.4 (SD=12.9); (2) 57.6 (SD=17.3)	Perceptual disorder: Pusher syndrome; time poststroke: 1–6 mo; %R hemisphere: 61%–80%R	Rehab (restitution); computer-generated interactive visual feedback training with Nintendo Wii balance board	Tech based; PT; 1-1; NR	Length: 40 min; frequency: 3× wk; n of sessions: 9	3/52 wk; 6/24 h
			Rehab (restitution); mirror visual feedback training	HCP led; PT; 1-1; NR	Length: 40 min; frequency: 3× wk; n of sessions: 9	3/52 wk; 6/24 h
Yun (2018); RCT; South Korea	n=36; mean: (1) 63.6 (SD=8.3); (2) 64.3 (SD=8.4)	Perceptual disorder: Pusher syndrome; time poststroke: 1–6 mo; %R hemisphere: 0%–20%R	Rehab (restitution and substitution); robot-assisted gait training with Lokomat	Tech based; NR; 1-1; in/outpatient	Length: 30 min; frequency: 5× wk; n of sessions: 15	3/52 wk; 7.5/24 h
Babyar (2018); cohort; the United States	n=10; range, 54–87	Perceptual disorder: Pusher syndrome; time poststroke: <1 mo; %R hemisphere: 81%–100%R	NIBS; tDCS	NIBS; NR; 1-1; NR	Length: 15 min; frequency: once; n of sessions: 1	1/365 d
			NIBS; galvanic vestibular stimulation	NIBS; NR; 1-1; NR	Length: 15 min; frequency: once; n of sessions: 1	1/365 d
Krewer (2013); RCT; Germany	n=25; range, 55–80	Perceptual disorder: Pusher syndrome; time poststroke: >6 mo; %R hemisphere: 81%–100%R	NIBS and rehabilitation (restitution and substitution); galvanic vestibular stimulation with exoskeleton-assisted locomotion and physiotherapy	NIBS; NR; 1-1; inpatient	Length: 20 min; frequency: unclear; n of sessions: unclear	Unclear; unclear

(*Continued*)

Table 2. Continued

Study: author; design; country	Population; (1) and (2) refer to participant groups within studies	Stroke	Intervention: approach; description	Delivery: materials; who; how; where	Session details	Duration
Nakamura (2014); N of 1; Japan	n=2; range, 83–86	Perceptual disorder: Pusher syndrome; time poststroke: 1–6 mo; %R hemisphere: 81%–100%R	NIBS and rehabilitation (restitution and substitution); galvanic vestibular stimulation with occupational therapy and physiotherapy	NIBS; NR; 1-1; inpatient	Length: 20 min; frequency: 5 d/wk; n of sessions: 10 with stimulation, 10 without	4/52 wk; 20/365 d
Colombo (2015); CR; Italy	n=1; age, 40 y	Perceptual disorder: somatosensory other; time poststroke: >6 mo; %R hemisphere: 0%–20%R	Rehab (restitution and substitution); 2-DOF elbow/shoulder manipulator and 1-DOF wrist manipulator	Tech based; NR; 1-1; inpatient	Length: unclear; frequency: 2× per day; n of sessions: unclear	3.5/52 wk
Jamal (2020); cohort; France	n=32; mean: 60.9 (SD=10)	Perceptual disorder: somatosensory other; time poststroke: >6 mo; %R hemisphere: 41%–60%R	Rehab (restitution); repetitive neck muscle vibration	Tech based; researcher; 1-1; NR	Length: 10 min; frequency: unclear	2/52 wk; unclear
Koo (2018); RCT; South Korea	n=24; mean: (1) 58.7 (SD=3.4); (2) 52.4 (SD=3.2)	Perceptual disorder: somatosensory other; time poststroke: <1 mo; %R hemisphere: 41%–60%R	NIBS; tDCS	NIBS; researcher; 1-1; inpatient	Length: 20 min; frequency: unclear; n of sessions: unclear	2/52 wk; unclear

Tech based: machinery, computer, and robotics. Unclear: information reported but not clear. ADL indicates activities of daily living; CC, case controlled; CR, case report; DOF, *df*; HCP, health care professional; Hz, hertz; NIBS, noninvasive brain stimulation; NR, not reported; OT, occupational therapist; PT, physiotherapist; RCT, randomized controlled trial; rTMS, repetitive transcranial magnetic stimulation; and Spec, specialist.

DISCUSSION

Summary of Findings

Our scoping review scoped the breadth and nature of perceptual disorder interventions poststroke, highlighting gaps in the evidence base. We identified 80 studies that explored predominantly visual or somatosensory perceptual problems, typically using a case report design. Interventions were frequently rehabilitative, with an approach that targeted improvements in the impaired function. Interventions most often involved direct training by an HCP, as well as those using technology-based devices and specialist equipment. Interventions reported were typically hospital based, lasting up to 4 weeks. Few captured outcomes beyond initial postintervention training effects. Perceptual and motor/sensorimotor skills were the most common outcomes reported. We noted an encouraging upward trajectory in the number of perceptual disorder (especially somatosensation) research reports, particularly RCT designs, since 2015.

Gaps in the Evidence

Our scoping review reveals the paucity of evidence informing perceptual disorder interventions poststroke. Key gaps include lack of research addressing perceptual disorders in pediatric populations; interventions for stroke-related hearing, taste, touch, and smell disorders; RCTs; and stakeholder-informed research. While a range of study designs are needed in early-stage intervention development, high-quality RCTs are important in building the evidence base related to treatment effectiveness. Of the 80 studies in this review, only 22 were RCTs; this is significantly lower than, for example, the 65 current trials in neglect found in a recent review.[38]

Perception Terminology

The range and complexity of perceptual terminology continues to be a challenge.[25] Despite achieving agreement on our definitions and included senses/disorders, we encountered challenges applying our a priori inclusion and exclusion criteria. Perception was inadequately reported, thus determining whether disorders affected perception, cognition, sensation, attention, or a mix of these was difficult. Inconsistent terms for similar conditions across pediatric and adult populations, and across senses, plus use of complex, Latinate terminology hindered transparency and clarity of interpretation. Clear statements of the nature of disorders, and how intervention rationale or mechanisms relate to perception, are needed. International, multidisciplinary consensus on the terminology used would serve to progress the field of research and improve awareness, multidisciplinary identification, and intervention for those affected.

Pediatric Perceptual Disorders

Five pediatric case reports on stroke survivors with visual perceptual problems were identified; this is in keeping with the extremely limited evidence base for pediatric stroke clinicians.[39] Some additional studies that addressed visual perception or cerebral/cortical visual impairment were identified, but as it was unclear whether impairments were stroke related, they were excluded from our review. Demographic information for both neonatal and later childhood perceptual impairment studies

Table 3. Hearing, Touch, and Mixed Perceptual Disorders: Details of Studies, Population, and Interventions

Study: author; design; country	Population; (1) and (2) refer to participant groups within studies	Stroke	Intervention: approach; description	Delivery: materials; who; how; where	Session details	Duration
Fechtelpeter (1990); CR; Germany	n=1; age, 41 y	Perceptual disorder: hearing other; time poststroke: NR; %R hemisphere: 0%–20%R	Rehab (restitution); sound identification (everyday noises) and matching to cards	Tech based; NR; 1-1; in/outpatient	Length: NR; frequency: NR; n of sessions: 7 (phase 1) and 10 (phase 2)	NR; NR
Fifer (1993); CR; the United States	n=1; age, 60 y	Perceptual disorder: auditory processing disorder; time poststroke: <1 mo; %R hemisphere: 81%–100%R	Rehab (substitution); wireless behind the ear contralateral routing of the signal hearing aid	Tech based; NR; 1-1; NR	Length: NR; frequency: NR; n of sessions: NR	8/52 wk; NR
Koohi (2017); cohort; England	n=9; range, 24–78	Perceptual disorder: auditory processing disorder; time poststroke: 1+ y; %R hemisphere: 41%–60%R	Rehab (substitution); speech in noise testing in sound attenuating chamber with/without FM system	Tech based; NR; 1-1; in/outpatient	Length: NR; frequency: NR; n of sessions: NR	NR; NR
Koohi (2017); CT; England	n=9; range, 24–78	Perceptual disorder: auditory processing disorder; time poststroke: 1+ y; %R hemisphere: 41%–60%R	Rehab (substitution); personal frequency modulated systems (Phonak iSense Micro receiver and Zoom link transmitter)	Tech based; other; self-delivery; home	Length: 6 h; frequency: daily; n of sessions: 70	10/52 wk; 420/24 h
Papathanasiou (1998); CR; England	n=1; age, 75 y	Perceptual disorder: auditory processing disorder; time poststroke: <1 mo; %R hemisphere: 0%–20%R	Rehab (restitution); auditory discrimination of minimal pairs	NR; other; 1-1; inpatient	Length: NR; frequency: NR; n of sessions: NR	NR; NR
Woolf (2014); N of 1; England	n=11; range, 44–81	Perceptual disorder: auditory processing disorder; time poststroke: >6 mo; %R hemisphere: NR	Rehab (restitution and compensation); phonological and semantic-phonological therapy	HCP led; other; 1-1; NR	Length: 60 min; frequency: 2× wk; n of sessions: 12	6/52 wk; 12/24 h
Zgaljardic (2013); CR; the United States	n=1; age, 39 y	Perceptual disorder: auditory processing disorder; time poststroke: 1–6 mo; %R hemisphere: 0%–20%R	Rehab (substitution); augmentative and alternative communication devices	Tech based; NR; NR; in/outpatient	Length: NR; frequency: NR; n of sessions: NR	10/52 wk; NR
Carey (1993); N of 1; Australia	n=8; range, 34–75	Perceptual disorder: tactile and proprioceptive deficit; time poststroke: 1–6 mo; %R hemisphere: 61%–80%R	Rehab (restitution and compensation); tactile discrimination and wrist proprioception training	Spec equipment; NR; 1:1; NR	Length: NR; frequency: NR; n of sessions: NR	NR; NR
Carey (2005); N of 1; Australia	n=5; range, 44–60	Perceptual disorder: tactile and proprioceptive deficit; time poststroke: 1–6 mo; %R hemisphere: 0%–20%R	Rehab (restitution and compensation); transfer of training using texture grids, fabrics, and proprioception stimuli	Spec equipment; NR; 1:1; NR	Length: 50 min; frequency: 3× wk; n of sessions: NR	NR; NR
	n=5; range, 47–88	Perceptual disorder: tactile and proprioceptive deficit; time poststroke: 1–6 mo; %R hemisphere: 41%–60%R	Rehab (restitution and compensation); stimulus-specific training of sensory discrimination, stimulus generalization of sensory discrimination	Spec equipment; NR; 1:1; NR	Length: NR; frequency: NR; n of sessions: NR	NR; NR
Carey (2011); RCT; Australia	n=50; mean: (1) 61.0 (SD=12.8); (2) 61.0 (SD=14.4)	Perceptual disorder: tactile and proprioceptive deficit; time poststroke: >6 mo; %R hemisphere: 41%–60%R	Rehab (restitution and compensation); sensory discrimination training using texture discrimination, limb sense, and object recognition	Spec equipment; NR; 1:1; NR	Length: 60 min; frequency: 3× wk; n of sessions: 10	3–4/52 wk; 10/24 h
			Rehab (unclear); nonspecific repeated exposure to tactile stimuli via grasping	Spec equipment; NR; 1:1; NR	Length: 60 min; frequency: 3× wk; n of sessions: 10	3–4/52 wk; 10/24 h
Hayashi (2004); CR; Japan	n=1; age, 55 y	Perceptual disorder: mixed hallucination; time poststroke: <1 mo; %R hemisphere: 81%–100%R	Pharmacological; carbamazepine; valproate	Pharmacological; unclear; 1:1; NR	Dosage: NR; frequency: NR; n of sessions: NR	NR; NR
Oppenlaender (2015); cohort; Germany	n=24; median: 64 (range, 42–84)	Perceptual disorder: visual and tactile disorder; time poststroke: 1–6 mo; %R hemisphere: 81%–100%R	NIBS; galvanic vestibular stimulation	NIBS; researcher; 1:1; NR	Length: 20 min; frequency: NR; n of sessions: 2	1/52 wk; <1/24 h
Carey (2016); cohort; Australia	n=11; range, 40–79	Perceptual disorder: tactile dysfunction; time poststroke: NR; %R hemisphere: 21%–40%R	Rehab (restitution and compensation); touch discrimination intervention: use of 3 texture grids with varying stimulus difficulty. Explore and discriminate the odd texture	Spec equipment; NR; 1-1; NR	Length: 45–60 min; frequency: 3× wk; n of sessions: 18	6/52 wk; 13.5–18/24 h

(*Continued*)

Table 3. Continued

Study: author; design; country	Population; (1) and (2) refer to participant groups within studies	Stroke	Intervention: approach; description	Delivery: materials; who; how; where	Session details	Duration
Enders (2013); cohort; the United States	n=10; mean: 60 (SD=9)	Perceptual disorder: tactile dysfunction; time poststroke: NR; %R hemisphere: NR	Rehab (restitution); vibrotactile noise: monofilament and 2-point discrimination with and without noise	Tech based; NR; 1-1; NR	Length: 2 h (noise, 1 min); frequency: once; n of sessions: 1	1/52 wk; 2/24 h
Fujimoto (2016); RCT; Japan	n=8; mean: 61.6 (SD=9.0)	Perceptual disorder: tactile dysfunction; time poststroke: >6 mo; %R hemisphere: 61%–80%R	NIBS; tDCS with tactile stimuli	NIBS; NR; 1-1; NR	Length: 15 min; frequency: once; n of sessions: 1	NR; <1/24 h
Kim (2015); RCT; South Korea	n=30; mean: (1) 54.7 (SD=3.1); (2) 59.4 (SD=8.6); (3) 56.4 (SD=11.9)	Perceptual disorder: tactile dysfunction; time poststroke: >6 mo; %R hemisphere: 21%–40%R	Rehab (restitution); pressure sense perception training on stable surface	Spec equipment; physiotherapist; 1-1; in/outpatient	Length: 30 min; frequency: 3× wk; n of sessions: 12	4/52 wk; 6/24 h
			Rehab (restitution); pressure sense perception training on unstable surface	Spec equipment; physiotherapist; 1-1; in/outpatient	Length: 30 min; frequency: 3× wk; n of sessions: 12	4/52 wk; 6/24 h
Kitisomprayoonkul (2012); RCT; Thailand	n=20; mean: (1) 54.7 (SD=8.6); (2) 58.0 (SD=11.9)	Perceptual disorder: tactile dysfunction; time poststroke: <1 mo; %R hemisphere: NR	NIBS; tDCS	NIBS; NR; 1-1; in/outpatient	Length: 20 min; frequency: once; n of sessions: 1	1/52 wk
Morioka (2003); RCT; Japan	n=28; mean: (1) 61.3 (SD=11.0); (2) 62.6 (SD=13.3)	Perceptual disorder: tactile dysfunction; time poststroke: 1–6 mo; %R hemisphere: 61%–80%R	Rehab (restitution); hardness discrimination exercise: discriminate hardness of sponge rubber placed under foot	Spec equipment; NR; 1-1; inpatient	Length: NR; frequency: 5× wk; n of sessions: 10	2/52 wk; NR

Tech based: machinery, computer, and robotics. Unclear: information reported but not clear. ADL indicates activities of daily living; CC, case controlled; CR, case report; CT, controlled trial; FM, frequency modulation; HCP, health care professional; Hz, hertz; NIBS, noninvasive brain stimulation; NR, not reported; OT, occupational therapist; PT, physiotherapist; RCT, randomized controlled trial; rTMS, repetitive transcranial magnetic stimulation; and Spec, specialist.

is required to support transparency, interpretation, and implementation of emerging research findings.

The limited intervention research involving pediatric stroke populations may reflect the conflicting evidence about the nature, extent,[40] and expectations of recovery due to neurodevelopmental plasticity.[41] Evidence of perceptual deficit persistence, and factors associated with pediatric resilience and recovery across sensory modalities, needs greater prominence.

Lack of Studies of Hearing, Taste, Touch, and Smell

Interventions for perceptual disorders relating to hearing, taste, touch, and smell were rarely identified; this may reflect stroke survivors' limited access to specialists, training, and consequently limited awareness of the frequency and impact of these disorders. Assessment and management of visual and somatosensory disorders are more established components of poststroke rehabilitation, giving the impetus to provide evidence to underpin care.[15] Establishing evidence of the prevalence, presentation, recovery, and impact of hearing, taste, touch, and smell perception disorders after stroke is required to inform clinical care and further research in this field.

High Proportion of Case Report Designs

Case reports and RCTs were the most frequent study designs included in this scoping review. Case reports described personalized interventions to individuals with multifaceted perceptual disorders, making their clinical relevance and representativeness difficult to establish. The recent growth in RCT reports is welcome and in keeping with other areas of stroke rehabilitation.[42] Trial participant numbers were low, however, raising questions about sufficient statistical power to determine clinical and cost-effectiveness. Inadequate reporting of treatment feasibility, fidelity, and outcome measures in RCTs and a lack of cohort and n-of-1 studies were evident. The use of a structured development process for perceptual disorder interventions would support exploration of mechanisms of action, dosage, and target group, informing the development and conduct of RCTs.[43,44]

Limited Involvement of Stakeholders

No included study reported the involvement of stroke survivors, carers, clinicians, or other stakeholders in the study design or conduct (as opposed to as participants). Similarly, we identified no qualitative studies

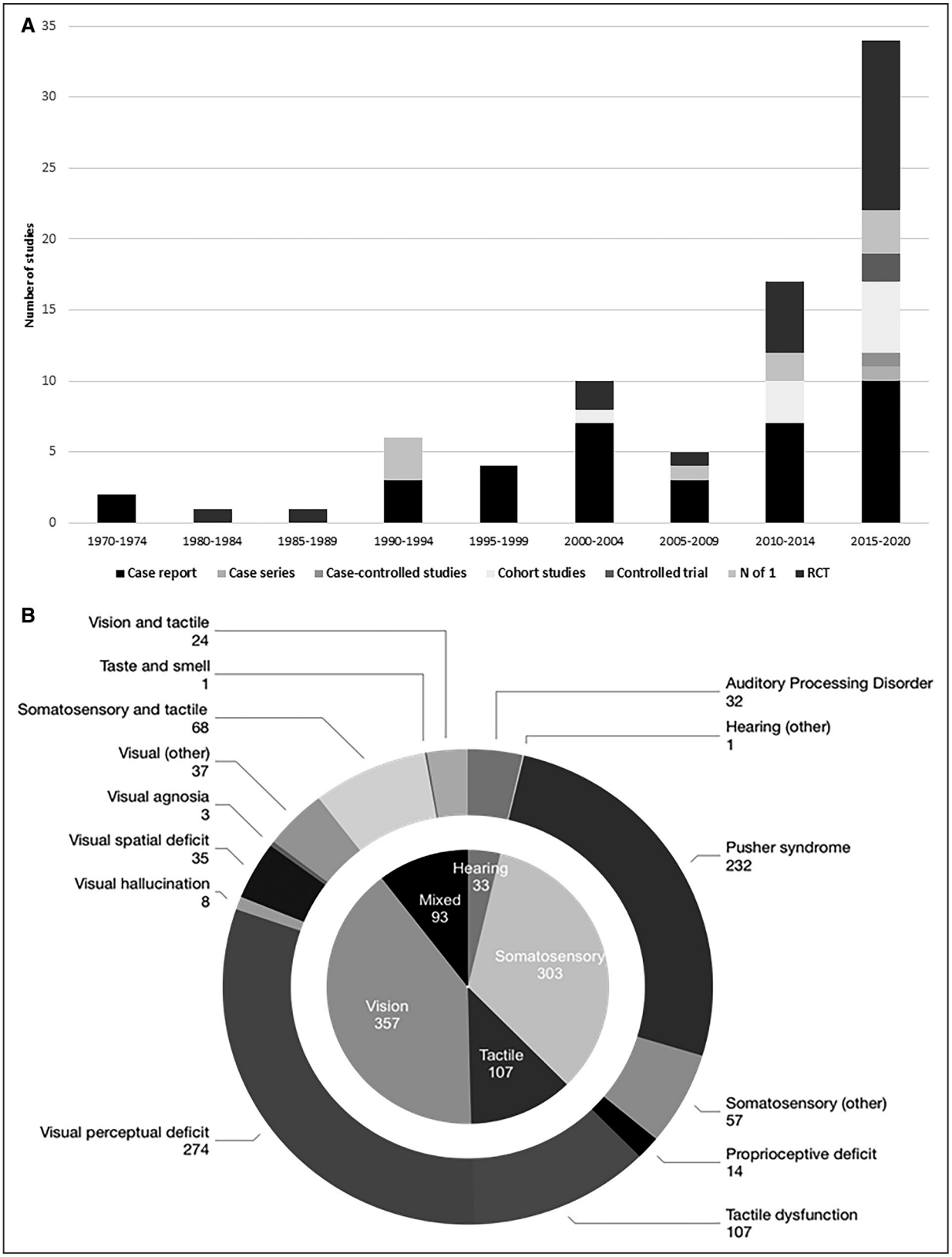

Figure 2. Study and participant data.

A, *The number of different study designs used, by year of publication.* **B**, *The total number of participants included in studies for each sense (inner ring) and each perceptual disorder (outer ring).* **C**, *The percentage of different study designs used for each sense.* **D**, *The number of interventions using a specific intervention approach, for each sense. *The categorization of perceptual deficit signified that study participants had a range of different perceptual issues or who were diagnosed using a test that did not specify the nature of the disorder. (Continued)*

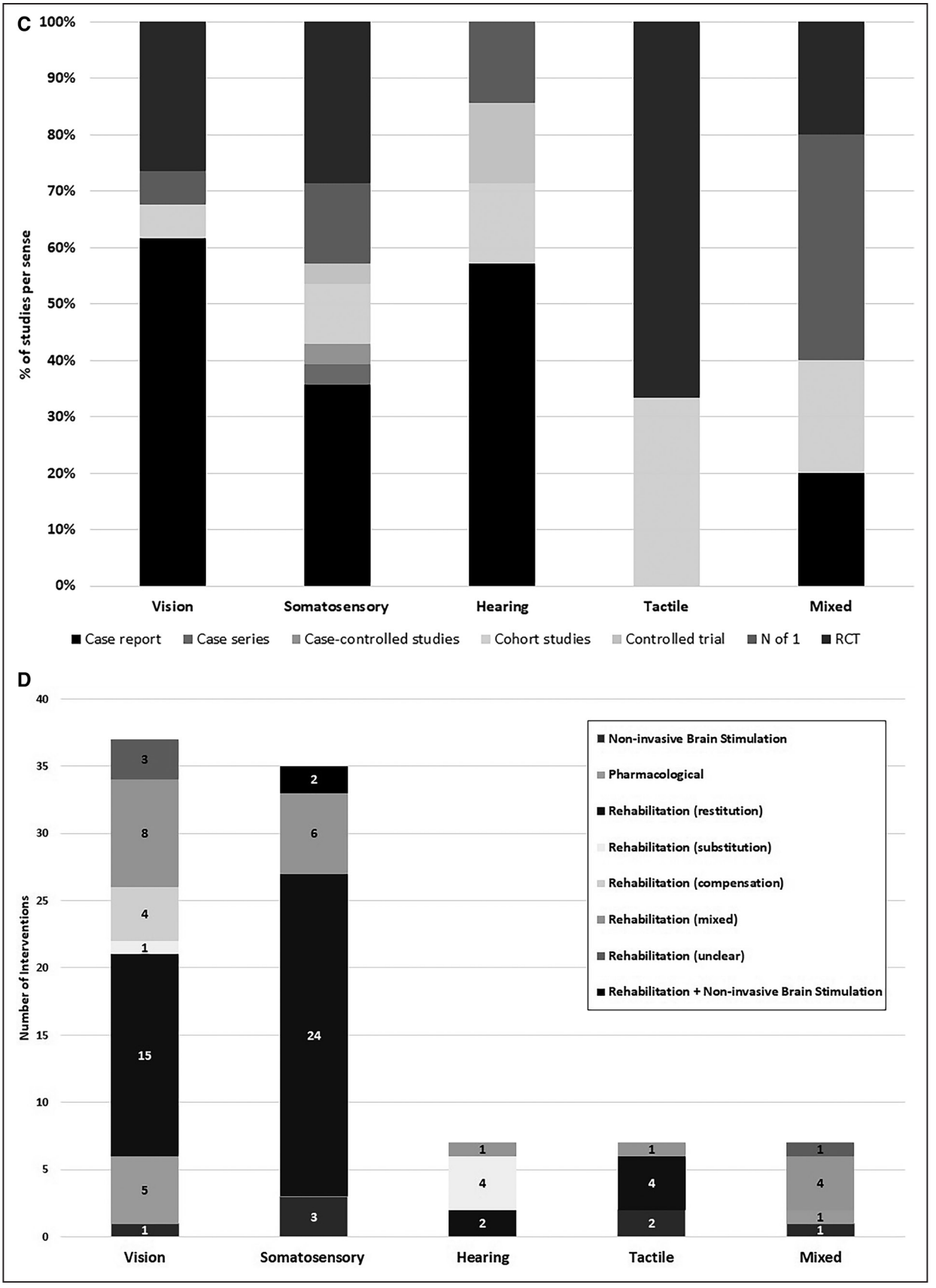

Figure 2 Continued.

Table 4. Outcome Measure Domains Reported

Outcome category	Hearing	Somatosensation	Tactile	Vision	Mixed	Total
Perceptual function	4	24	6	22	4	61
Motor/sensorimotor ability		21	2	9		33
Activities of daily living	1	12		5		18
Sensation		4	2	6		12
Cognition		1		8		9
Mobility, navigation, and safety		3	1	1		5
Neurological function		2	1	1		4
Language	2			2		4
Adverse events		1	1	1		3
Extended activities of daily living		1		1		2
Attention		2				2

We found no outcome data on discharge destination, economic outcomes, feasibility and acceptability, impact on family, friends, and carers, impact on rehabilitation, pediatric-specific measures of education and development, psychological and mental health, quality of life, social activities, and participation. Impact on rehabiliation relates to whether a perception intervention would have an effect on an individual's ability to engage with, and benefit from, rehabilitation for other poststroke impairments.

exploring experiences of stroke survivors, carers, or clinicians. Other areas of concern were a lack of real-world, community-based studies; feasibility or economic outcomes; follow-up post-initial posttreatment evaluations; and outcomes capturing transfer of intervention effects to daily life. The benefits of stakeholder involvement are well recognized[45] and would enhance the relevance, implementation, and impact of future research.

Strengths and Limitations

Our scoping review used a broad and rigorous search of electronic databases and Grey literature, adopting a comprehensive definition of perceptual disorders. Despite these efforts, due to the complex nature of the topic and terminology, some relevant articles may have been missed. Our multidisciplinary clinician-research team had expertise in review methodologies, stakeholder involvement, stroke rehabilitation, cognitive disorders, psychology (adult and pediatric), and hearing, taste, smell, somatosensory, and vision disorders. In addition, involvement of our stakeholder group maximized the relevance and accessibility of our findings. In the absence of a universally accepted intervention categorization, we utilized an existing method to support categorization consistency, relevant to perceptual disorder research[34] but which may not necessarily directly align with other categorization approaches.[44] As a scoping review, we did not conduct quality appraisal, and thus comment on quality or generalizability of study findings was not possible.

Conclusions

Our review provides a comprehensive overview of the evidence relating to interventions for perceptual disorders following adult and childhood stroke. Interventions are under-researched, and the terminology used is a barrier to understanding. Key evidence gaps include interventions for pediatric populations, and for stroke-related hearing, taste, touch and smell perception disorders. Rigorous study design, conduct, and reporting, incorporating fuller involvement of stroke survivors, carers, and clinicians, is needed to address perceptual disorders after stroke.

ARTICLE INFORMATION

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Supplemental Material

Supplemental Methods S1–S3
Tables S1–S6

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